Terrestrial Planet Finder Mission

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Terrestrial Planet Finder: Briefing to the Origins Subcommittee

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TPF Science Goals

- Search for and characterize Earth-like planets around a statistically significant number of nearby stars
- Examine detected planets for habitability and signs of life
- Carry out a program of general astrophysics
  - As appropriate to the instrumental capabilities of TPF without incurring significant additional capital cost

TPF represents one of the defining goals of the Origins Program

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TPF Status

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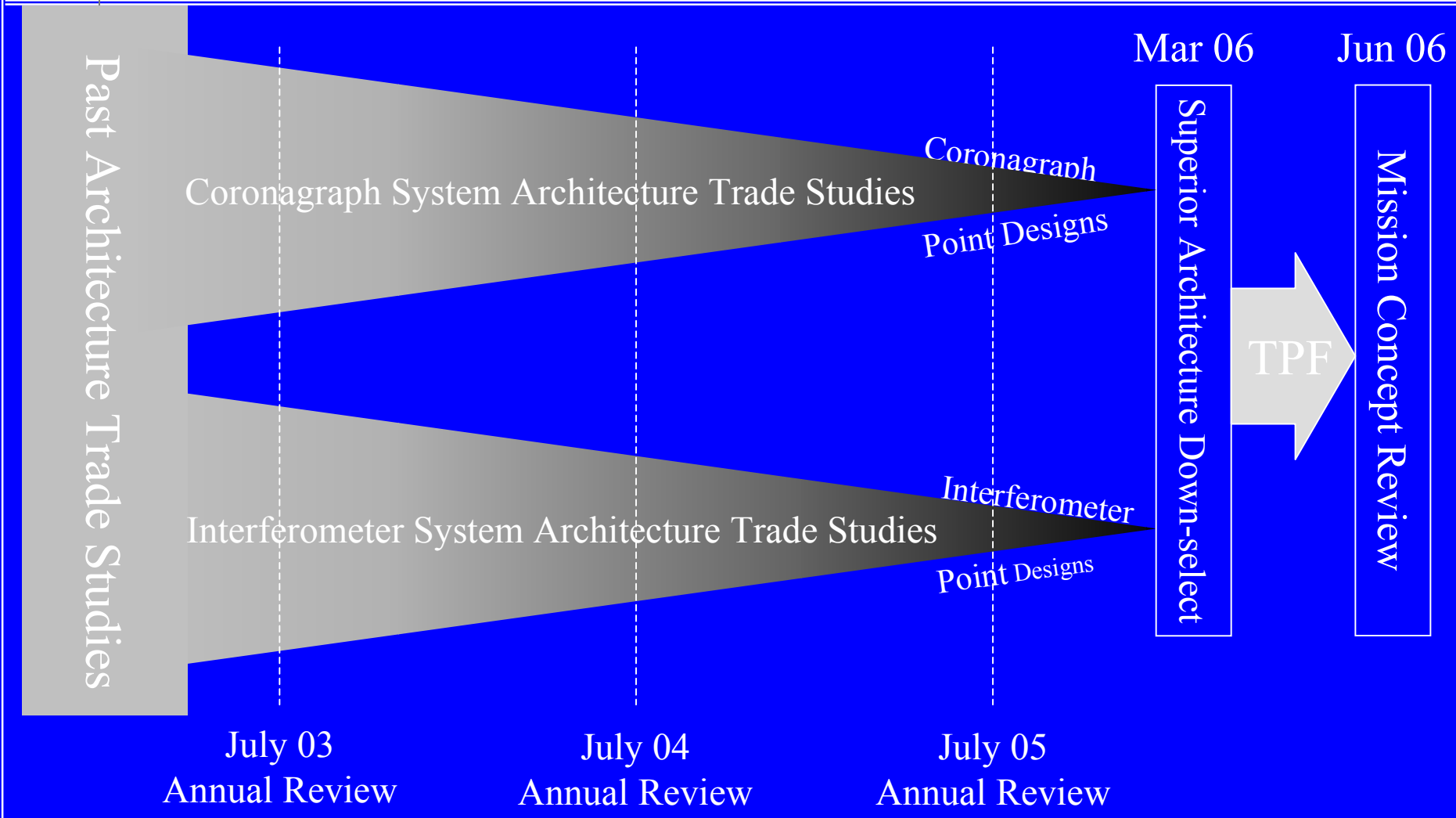
- 2 years of industry/academic study, examination of >60 designs→
  - Visible light coronagraph
  - Nulling IR interferometer on structure or free flying spacecraft
- TPF project and new TPF-SWG assessing 4 missions designs: 2 architectures each with 1 large and 1 small implementation
  - Science team is defining minimum and desired mission science requirements
  - Refine choices (architecture and scope) iteratively with science team
  - Choose architecture for 2007 Phase A→Phase C/D start in 2010 →launch in 2015
- Project has generated a detailed technology plan
  - Supports architecture selection and eventual implementation
  - Reviewed by Headquarters and Independent Review Team
  - Extensive involvement by industry and university researchers
- Project defining roadmap for precursor science

NASA is working closely with ESA on joint TPF/Darwin mission

Selection of Final Architecture



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TPF-SWG

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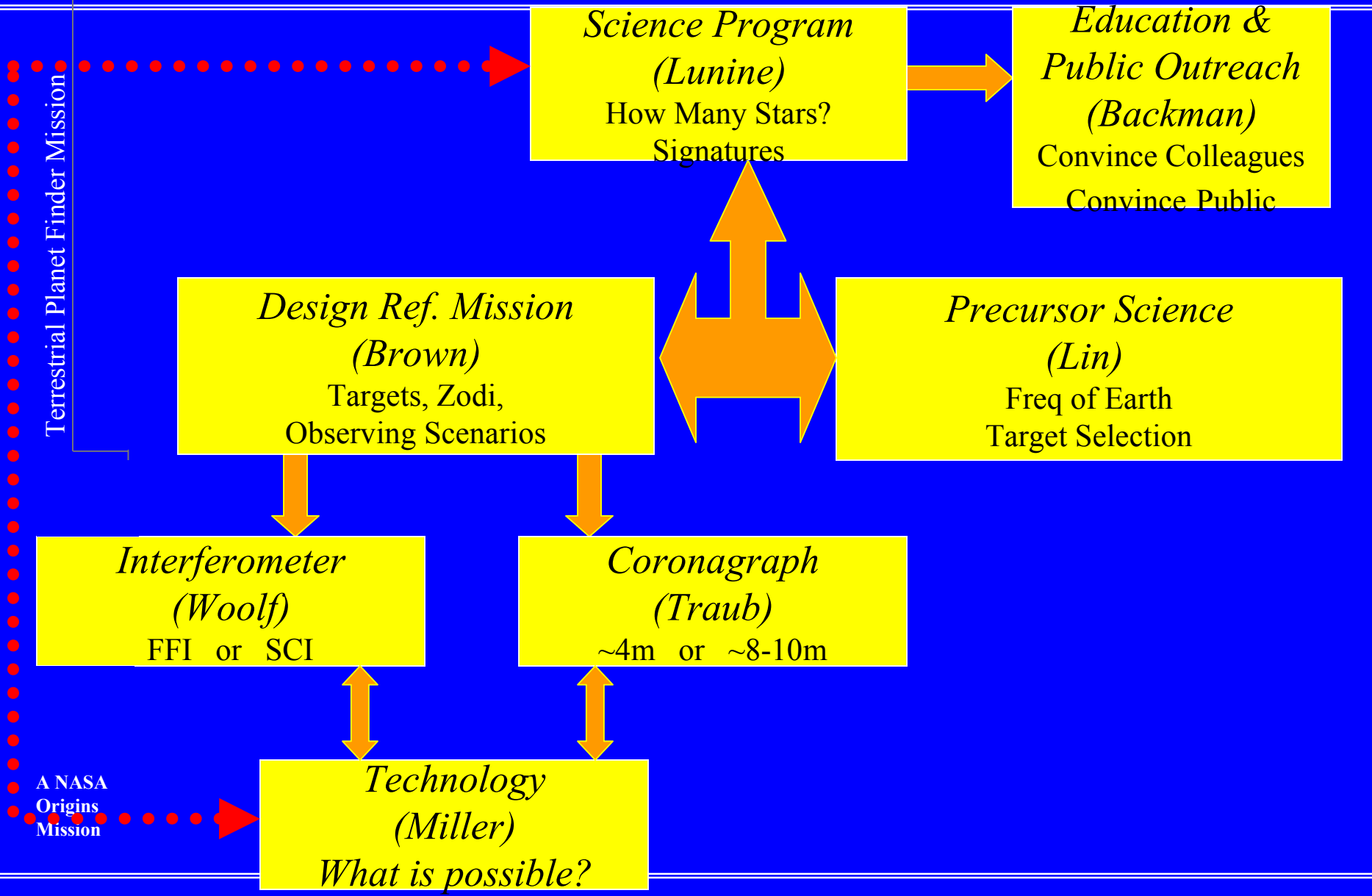
Name	Organization	Name	Organization
Dana Bachman	Franklin & Marshall College	Gary Melnick	CfA
Charles Beichman	JPL, Chair, TPF Project Scientist	Bertrand Mennesson	JPL
Robert Brown	STScI	David W. Miller	MIT
Christopher Burrows		Charlie Noecker	Ball Aerospace
William Danchi	GSFC	Sara Seager	Carnegie Institution
Malcolm Fridlund	ESA, Darwin Project Scientist	Gene Serabyn	JPL
Eric Gaidos	University of Hawaii	William Sparks	STScI
Phil Hinz	University of Arizona	David Spergel	Princeton Univ.
Kenneth Johnston	US Naval Obs.	Wesley Traub	CfA
Marc Kuchner	CfA	John Trauger	JPL
Douglas Lin	UC Santa Cruz	Ted von Hippel	University of Texas
Jonathan Lunine	University of Arizona	Neville Woolf	University of Arizona
Vikki Meadows	JPL	ESA TBD	

- Develop science requirements for a mission to detect and characterize Earth-like planets beyond our Solar System.
- Comment on critical and enhancing technologies for TPF
- Evaluate observing capabilities of TPF including ancillary science
- Assist NASA in developing a long-term strategy for the systematic exploration of nearby planetary systems, including not only TPF, but other space activities and research opportunities as well

Science Requirements Flow



Four Hard Things About TPF

- Sensitivity (relatively easy)
  - Detection in hours → spectroscopy in days.
  - Integration time ∝ (distance/diameter)^4
  - Need 12 m^2 of collecting area (≥4 m) for star at ~10 pc
- Angular resolution (hard)
  - 100 mas is enough to see ~25 stars, but requires ≥4 m coronagraph or ≥20 m interferometer
  - Baseline/aperture ∝ distance
- Starlight suppression (hard to very hard)
  - 10^{-4} to 10^{-6} in the mid-IR
  - 10^{-8} to 10^{-10} in the visible/near-IR
- Solar neighborhood is sparsely populated
  - Fraction of stars with Earths (in habitable zone) unknown
  - Unknown how far we need to look to ensure success
  - Surveying substantial number of stars means looking to ~15 pc

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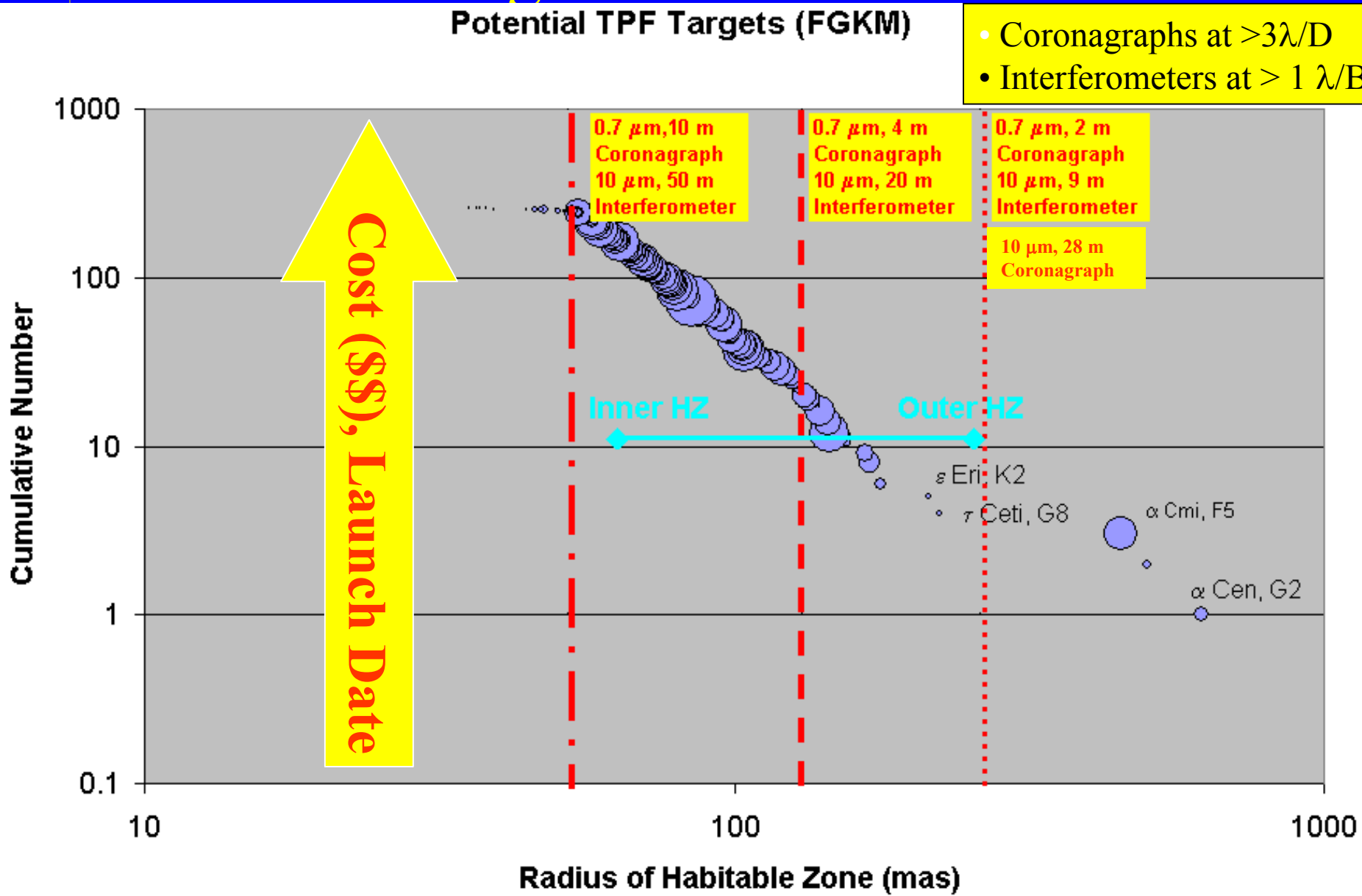
The Challenge of Angular Resolution

- Coronagraphs at >3λ/D
- Interferometers at > 1 λ/B



Two Architecture Classes & Two Mission "Scopes"

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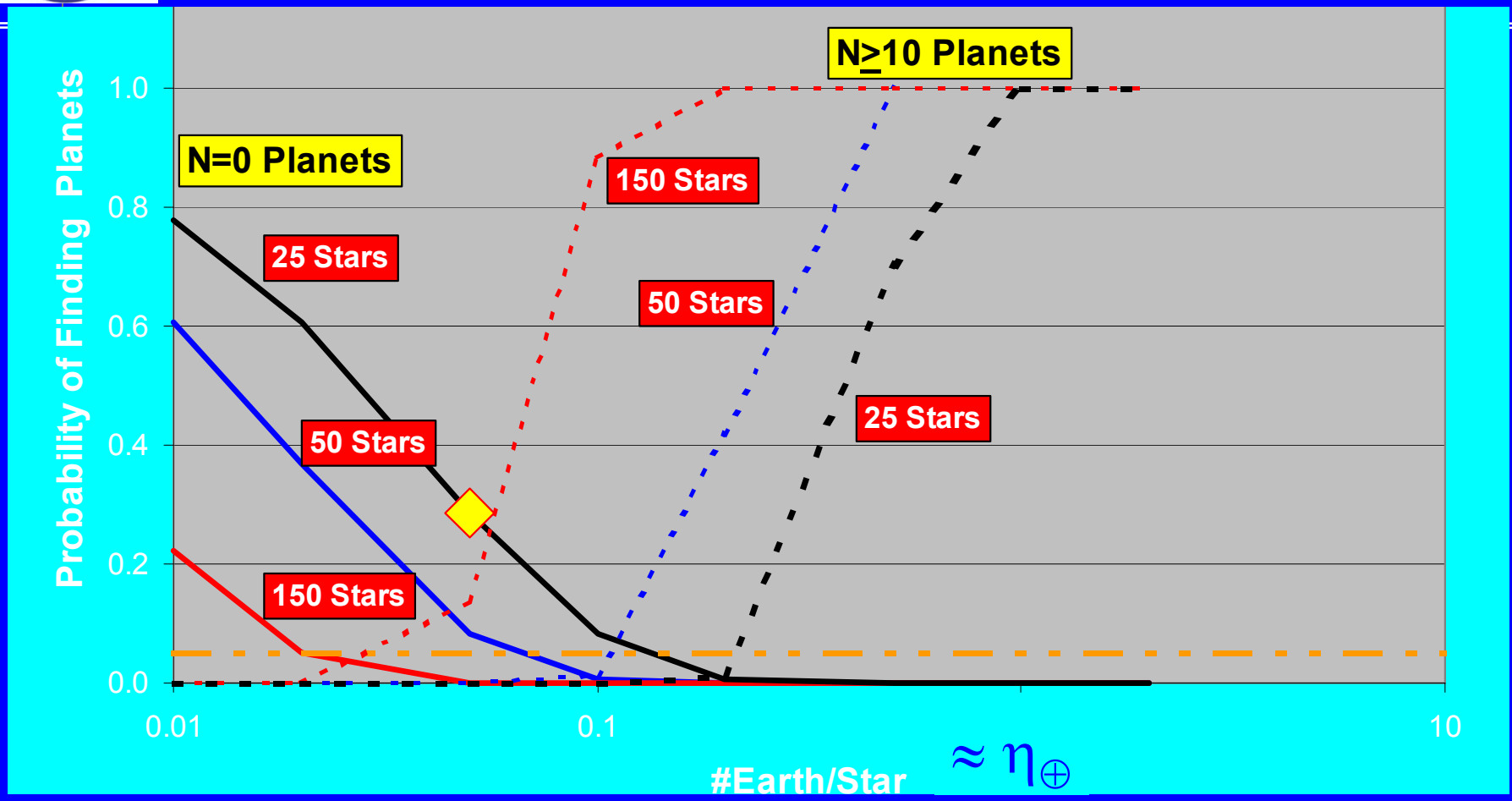
- Two Coronagraphs
  - Full scope mission of 150~250 stars requiring 8-10 m aperture
  - Reduced scope mission of 25-50 stars requiring 4 m aperture

- Two Interferometers
  - Full scope mission of 150~250 stars requiring formation flying interferometer (> 50 m baseline)
  - Reduced scope mission of 25-50 stars requiring ~25 m baseline

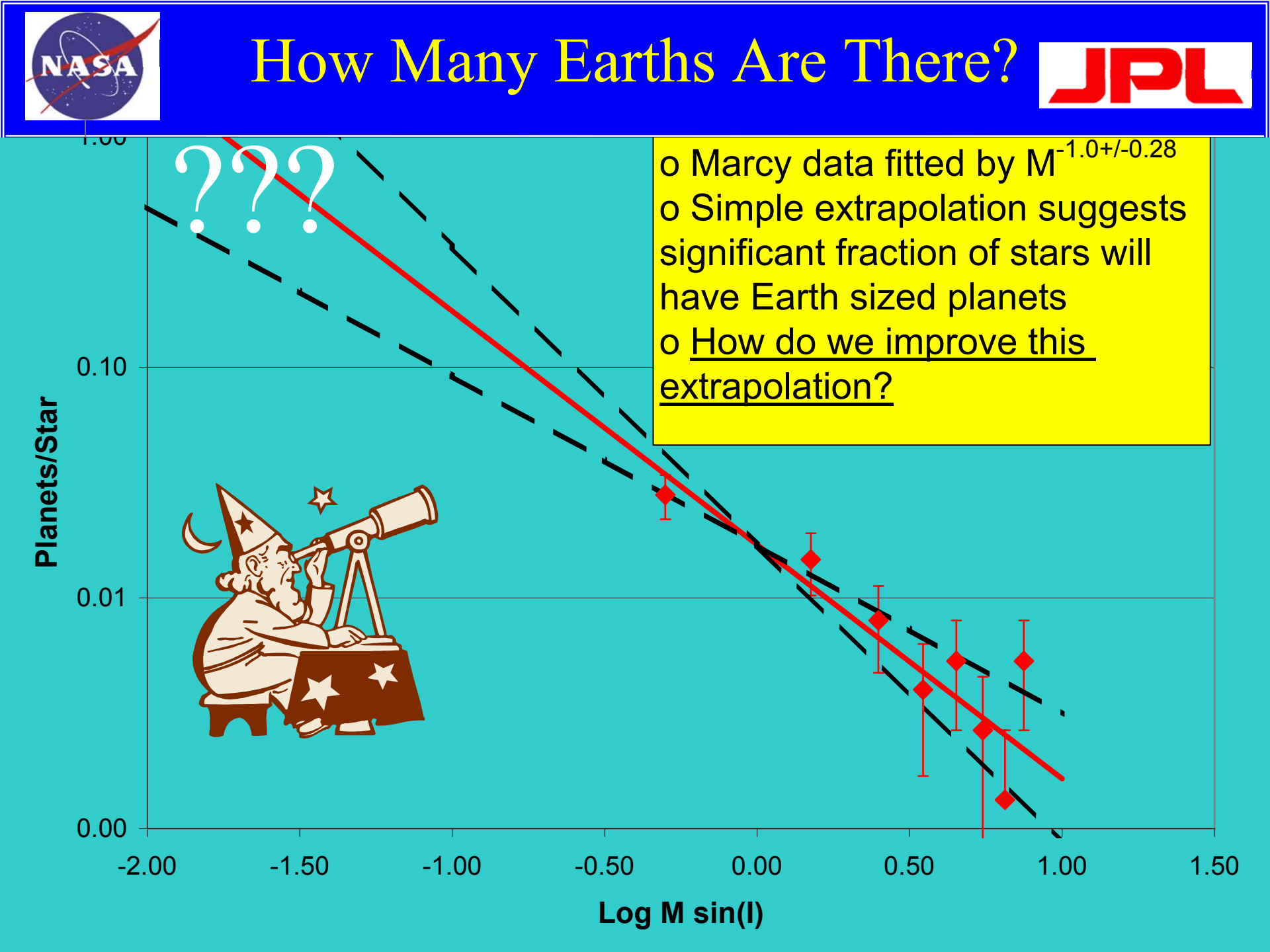
How Many Planets Are Enough ?



- How many stars to avoid mission failure ($N_p = 0$)
- How many stars to ensure enough planets ($N_p = 5, 10$?)

$\eta_\oplus$ → # Stars →Dist→(Aperture, Baseline)→Cost→Schedule

How Many Earths Are There?



How Will We Learn About Earths?

- Theoretical interpretation of available data
  - Extrapolation from giant planets from RV, transits, microlensing
  - Interpretation of exo-zodiacal disks from SIRTF, Keck-I/LBTI
    - EZ also important for target characterization
  - Astrometric results on giant planets (Keck-I outriggers)
    - Extrapolation from 10 M_{earth} → 1 M_{earth}
- Transit, micro-lensing data from ground and space
  - MOST/COROT (2006)
    - Will search for large earths on day/month orbits around 10^3 stars
  - Kepler/Eddington (2008-10)
    - Earths on day/month orbits
- Project and TPF-SWG are developing science roadmap for precursor science to address this and other critical questions
  - NASA will fund major precursor science program addressing this question (5-10% of TPF budget) through new amendment to ROSS NRA
  - Define key data needed for TPF from other facilities
    - SIRTF, SIM, Keck-I, LBT-I, VLT-I, etc.
  - Define key theoretical programs to support

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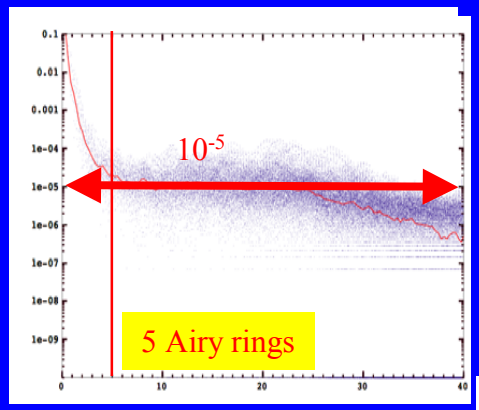
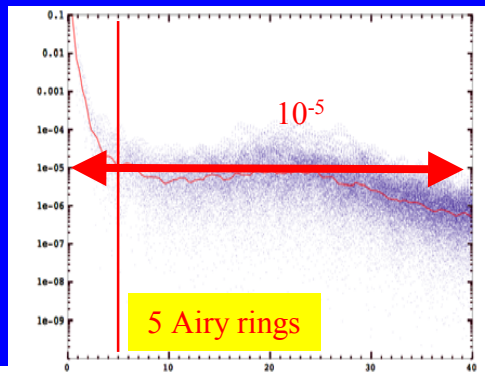
Coronagraph Status

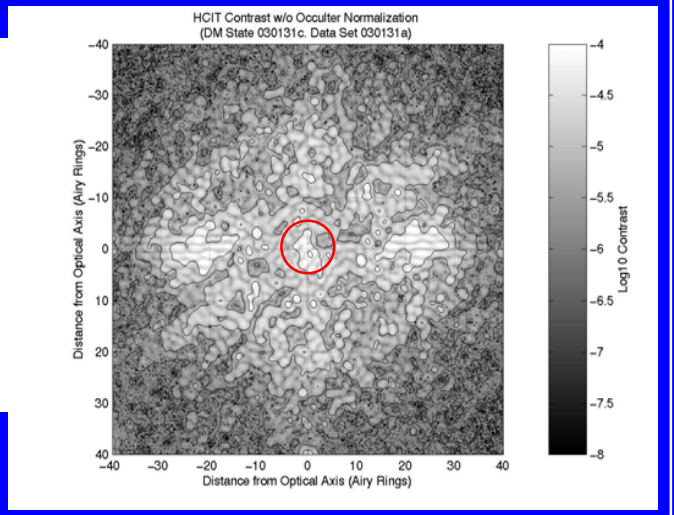
- High Contrast Imaging Testbed operational
- Current contrast limited to slightly better than 10^{-5} due to DM imperfections and lab seeing
  - Experiments match models
- New DM due from Xinetics in March
- Testbed moving into Vacuum Chamber
- Kodak selected to provide large (1.8m), high precision (<5 nm) Technology Demo Mirror



Measured contrast 2/6/03 Imperfect DM, lab seeing, Thermal variations



Model contrast 2/6/03 Imperfect DM. No seeing, thermal



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IR Nulling Results

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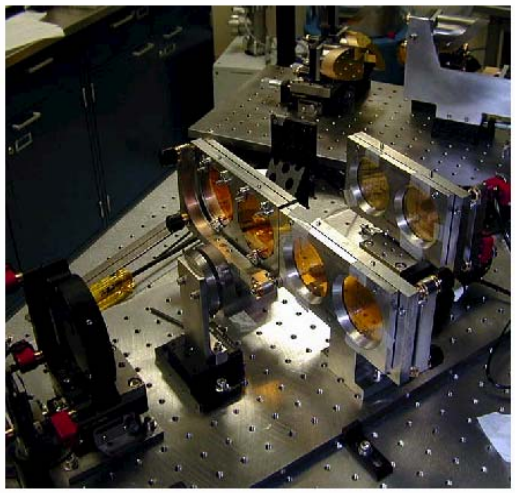
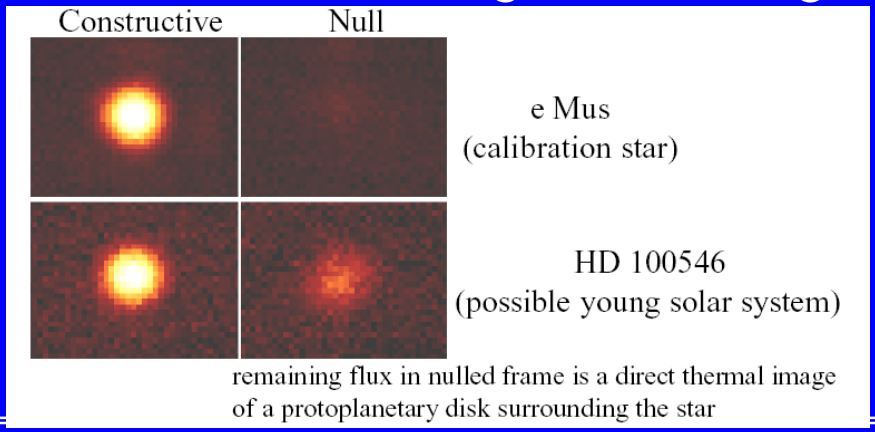


View of the TPF mid-infrared Mach-Zehnder breadboard nuller

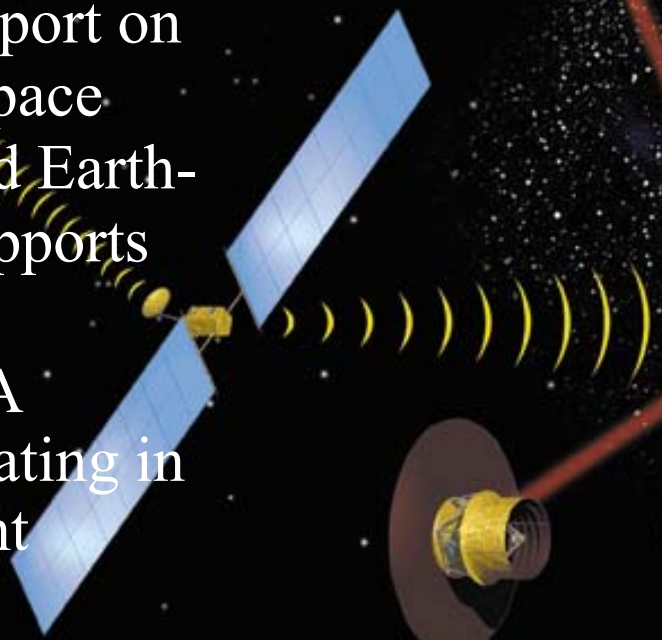
- JPL Modified Mach-Zender configuration.
  - 700,000: 1 laser null (10.6 um) ➔ ***1.4e-6 null***
  - Maintained for ~1 min with minor pathlength tweaks by hand
  - Next steps:
    - Add spatial filter
    - Active pathlength stabilization
  - →Hit 1e-6 null target broadband

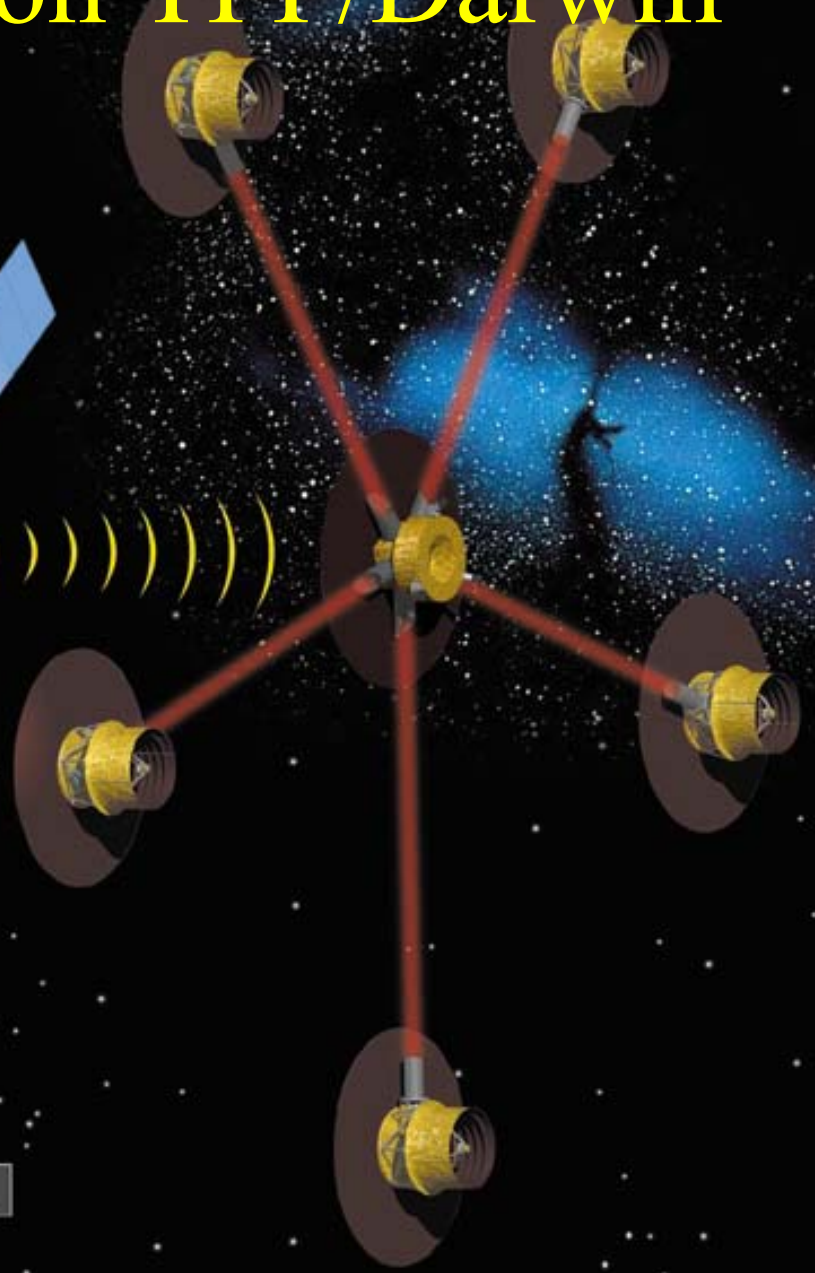
UofA group (Hinz et al) have nulling system (BLINC) on MMT demonstrating active nulling



Collaboration on TPF/Darwin

- Strong ESA/NASA interest in joint mission
  - Inter-Agency report on "Prospects of Space Missions to Find Earth-like Planets" supports collaboration
- Formal NASA-ESA discussions culminating in Letter of Agreement
  - Collaborative architecture studies
  - Coordination on schedules, technology planning and development





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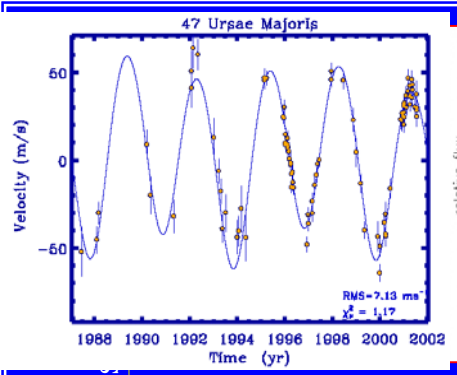
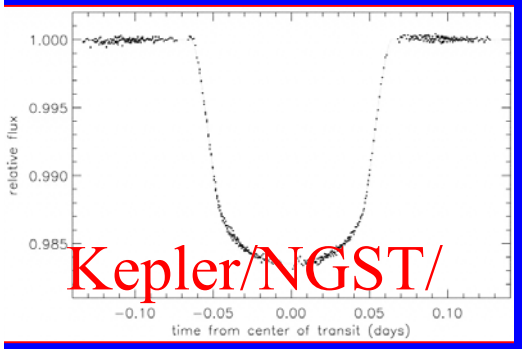
ALCATEL

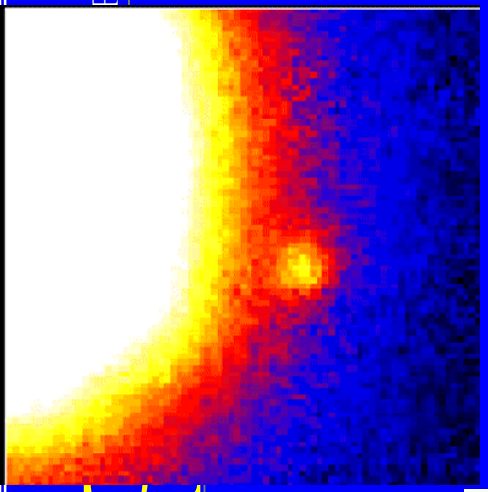
Pre-TPF Study Will Span Wavelengths, Techniques, Years, Ground and Space, Theory and Observation

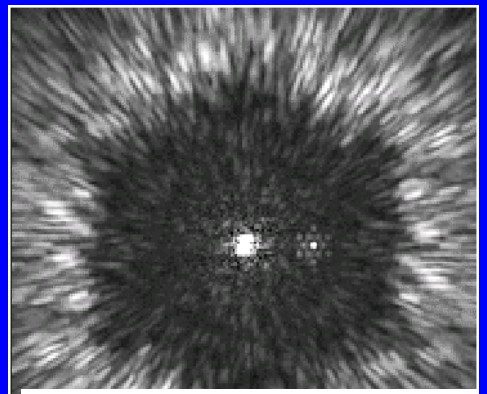




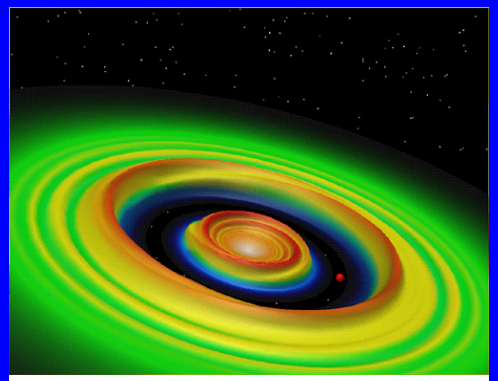
Kepler/NGST/

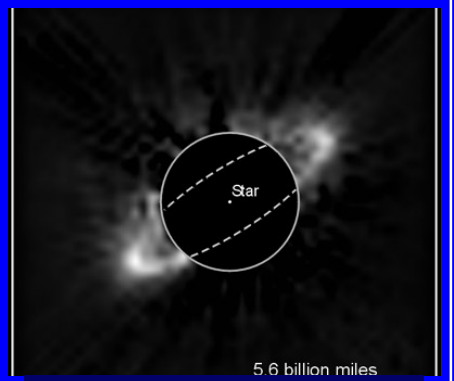
Finder Mis

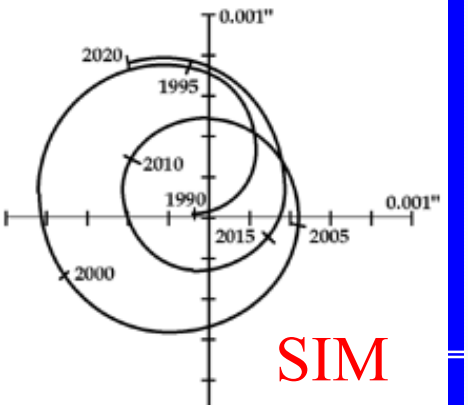




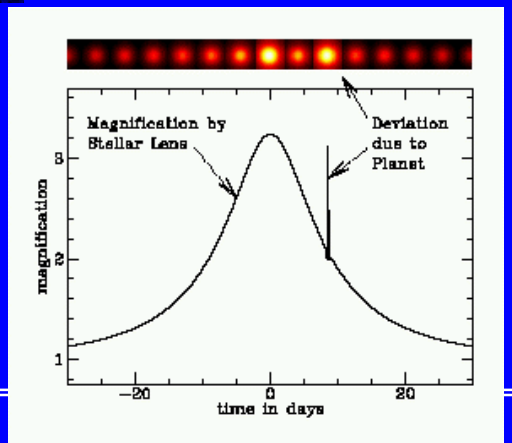
NGST/TPF-Lite

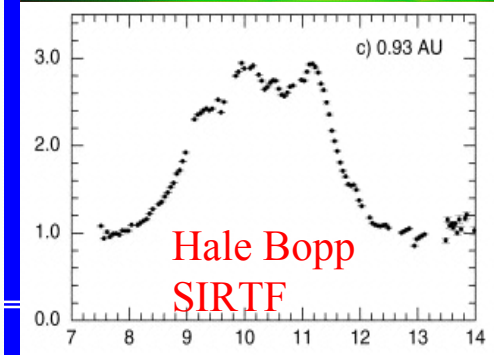




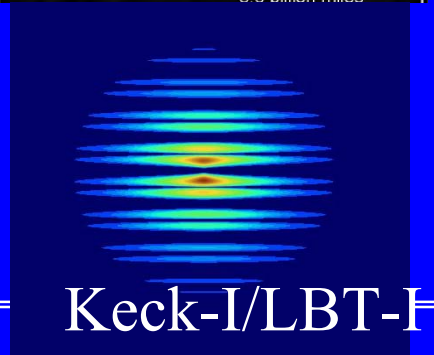


SIM





Hale Bopp
SIRTF



Keck-I/LBT-I

Planet Finding Is A Decades-Long Undertaking

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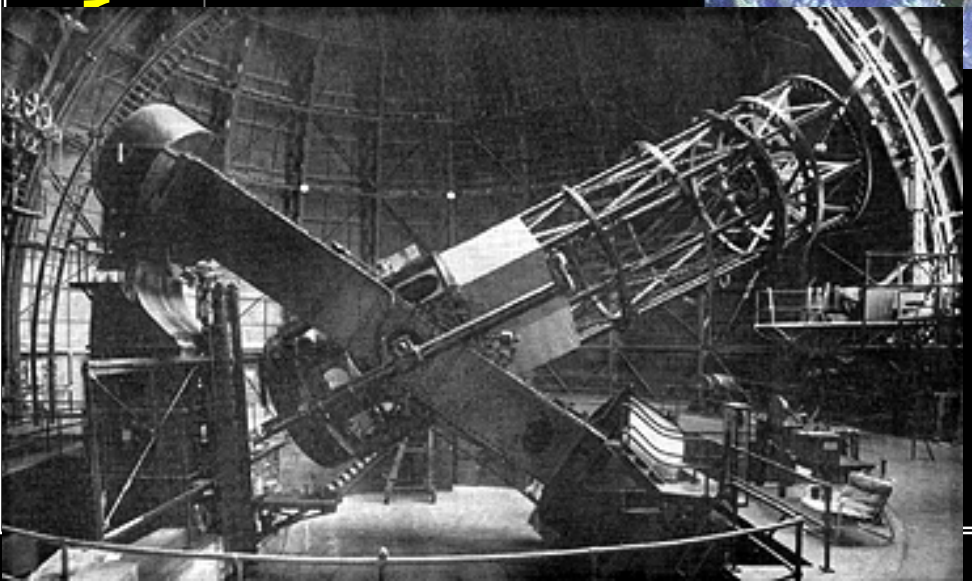
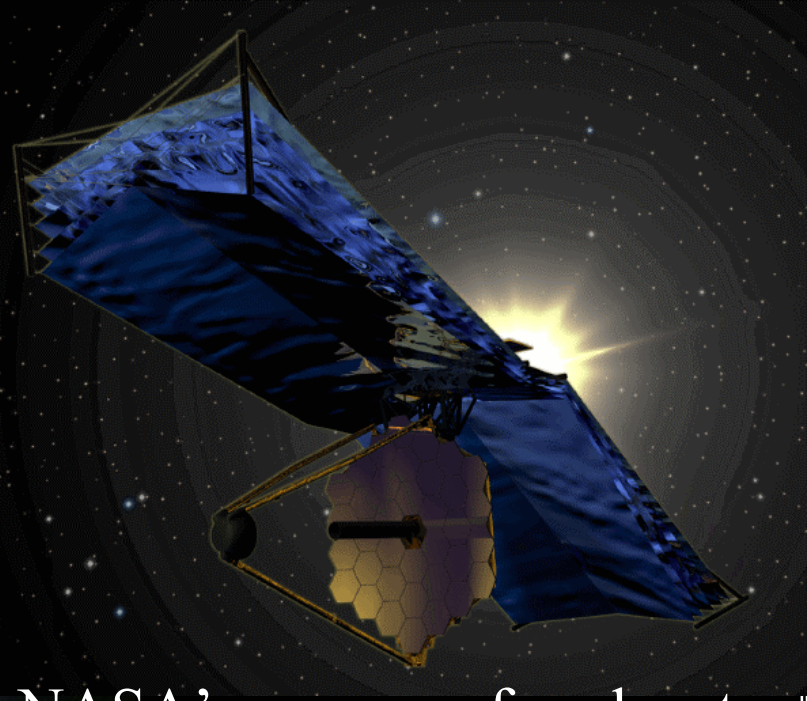
Like cosmology, the search for planets and life will motivate broad research areas and utilize many telescopes for decades to come





- NASA's program for planet finding will be broad and rich, with results emerging on many time scales, from the immediate to the long-term
- There are exciting, mid-term ways to detect giant planets and the nearest Earths
- We are making progress on key technologies